I. C. 6874 FEBRUARY 1936

DEPARTMENT OF THE INTERIOR

UNITED STATES BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

METHANE-INDICATING DETECTORS PROVE DEPENDABLE IN SAMPLING AIR IN ANTHRACITE MINES

BY

R. D. CURRIE

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DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

METHANE-INDICATING DETECTORS PROVE DEPENDABLE IN SAMPLING AIR IN ANTHRACITE MINES[1]

By R. D. Currie[2]

The practicability and dependability of two permissible methane-indicating detectors recently developed were proved conclusively by extensive tests in the return airways of all mines operating in the anthracite region in most of which samples and readings were taken with one or the other of the two indicating detectors. These detectors proved dependable and accurate within practical limits, and their general use should be encouraged as an aid to better ventilation, more accurate control of air currents, and greater safety in mines.

DESCRIPTION OF DETECTORS

The U.C.C. and M.S.A. detectors approved by the Bureau of Mines as permissible under Schedule 8B were used in this study.

A complete description of the U.C.C. detector was published in Bureau of Mines Bulletin 331, following a series of tests to determine the practicability of the various detectors approved at that time. The M.S.A. detector was developed and improved after the publication of this bulletin and is therefore not mentioned in the description of the four permissible methane detectors approved before 1930.

The U.C.C. and M.S.A. detectors have the following features in common: They are operated electrically and use the Wheatstone-bridge principle (modified) based on the combustion of methane in contact with an electrically heated platinum filament; they have indicating meters which give readings in direct percentage of methane; and they are portable, are connected with permissible electric cap lamps, and are permissible for use in gassy mines.

Figure 1 shows the details of the U.C.C. detector and permissible electric cap lamp. This detector consists of four parts connected by flexible electric conductors: Detector head A; meter and bridge compartment B; lead-acid storage battery C; and cap-lamp attachment D.

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Figure 2 shows the M.S.A. detector, which consists of three parts connected by flexible electric conductors: Alkaline storage battery, permissible electric cap lamp, and aluminum box containing filaments, rheostats, and meter.

The electric circuits of these detectors are shown diagrammatically in figure 3.

The fundamental principle on which the detectors operate - change in electrical resistance with change in temperature of a platinum filament - has been known for years; a methane detector based on this principle was invented by G. Leon about 1902[3], but the device never was perfected to the practical stage. A similar device was described in 1914 by G. J. Ralph[3] as an improvement of his earlier device[4], but it proved a failure in detecting firedamp. No commercial adaptation of the principle used in these devices was perfected until the U.C.C. detector was submitted to and approved by the Bureau of Mines in November 1926 under approval 702.

Although based on the same general principle, the M.S.A. detector overcomes two of the weaknesses of the U.C.C. detector - relatively short life of the filament and inability to set the instrument to zero except in strictly fresh air - by considerable variation in electrical circuit and by enclosing the heated filament in the meter compartment where it is exposed to methane only during actual sampling.

As the filament in the M.S.A. detector is exposed to methane only during actual testing, its life is prolonged in inverse proportion to the number of tests made and percentages of methane encountered. It can be set to zero anywhere in a mine by turning on the electric current and allowing the filament to burn out any methane in the small filament compartment. The atmosphere in the compartment is then inert and approximates a condition of fresh air insofar as combustible gas and the consequent temperature of the filament are concerned; these two improvements (especially the latter) are very important to the average user of this type of equipment.

PRACTICAL USE OF METHANE DETECTORS

At the request of the Pennsylvania State Department of Mines the United States Bureau of Mines in September 1932 began a series of tests to determine the methane content of air in the return airways of the mines in the anthracite region. Soon afterward it was decided to use the U.C.C. indicating detector for immediate indications of the percentage of methane present and to determine its practicability.

3/ Ralph, G. J., A Portable Electrical Gas-Detecting Device for Use with Miners' Lamps: Trans. Inst. Min. Eng., vol. 48, 1914-15, pp. 79, 306-309.

4/ Ralph, G. J., The Holmes-Ralph Gas-Detecting Portable Electric Lamp: Trans. Inst. Min. Eng., vol. 42, 1911, p. 201.

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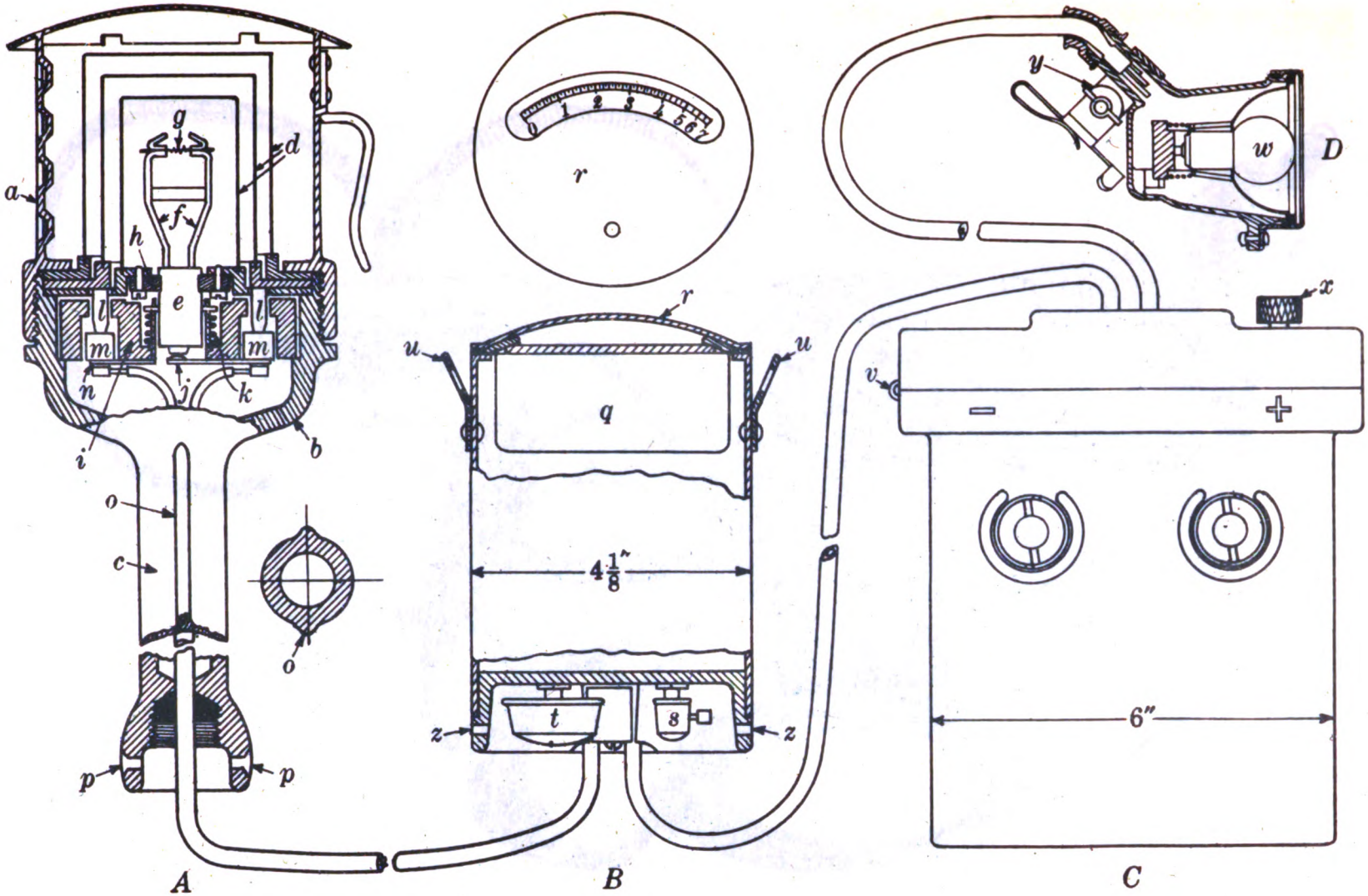

Figure 1.— Details of U.C.C. permissible methane-indicating detector.

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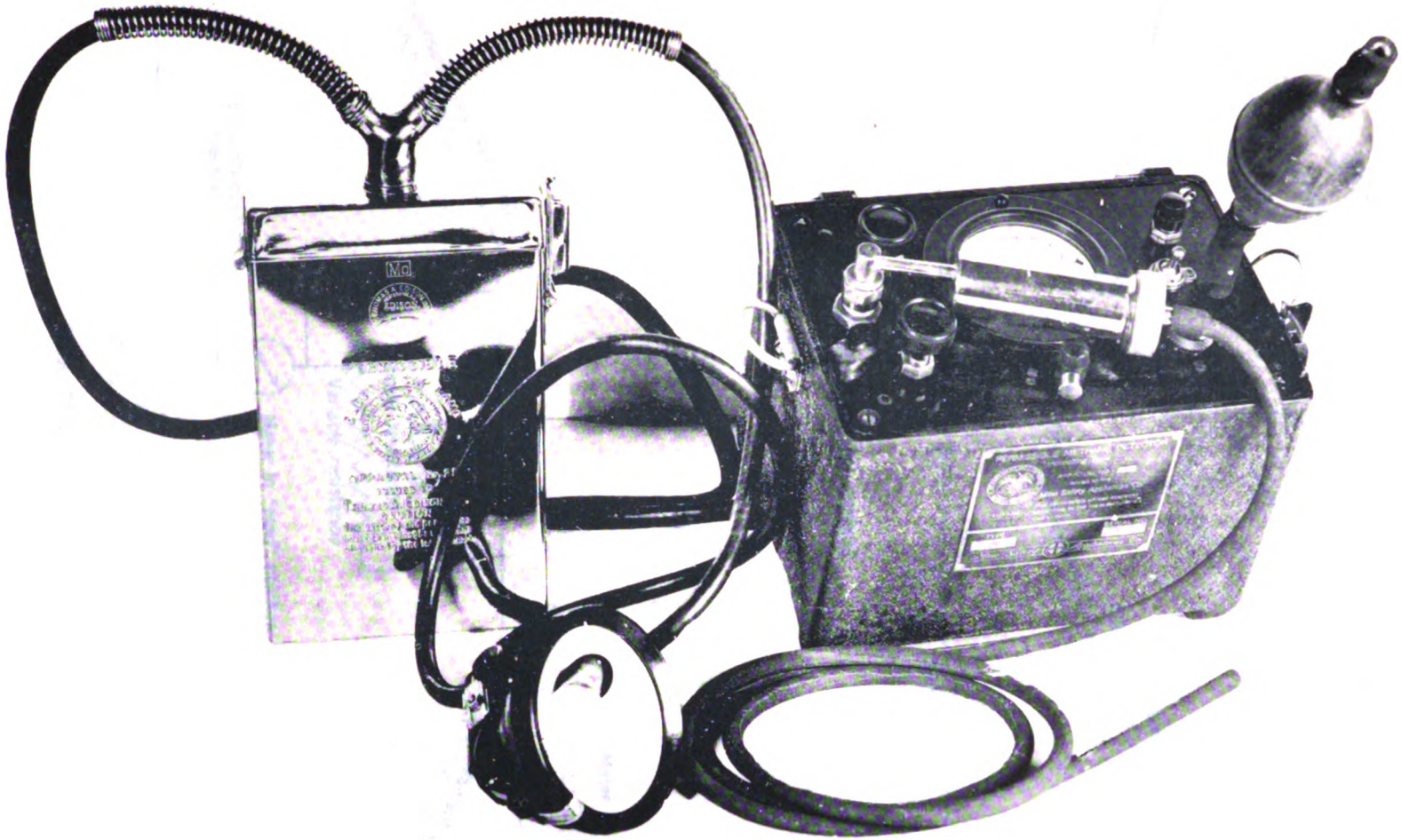

Figure 2.— M.S.A. permissible methane-indicating detector.

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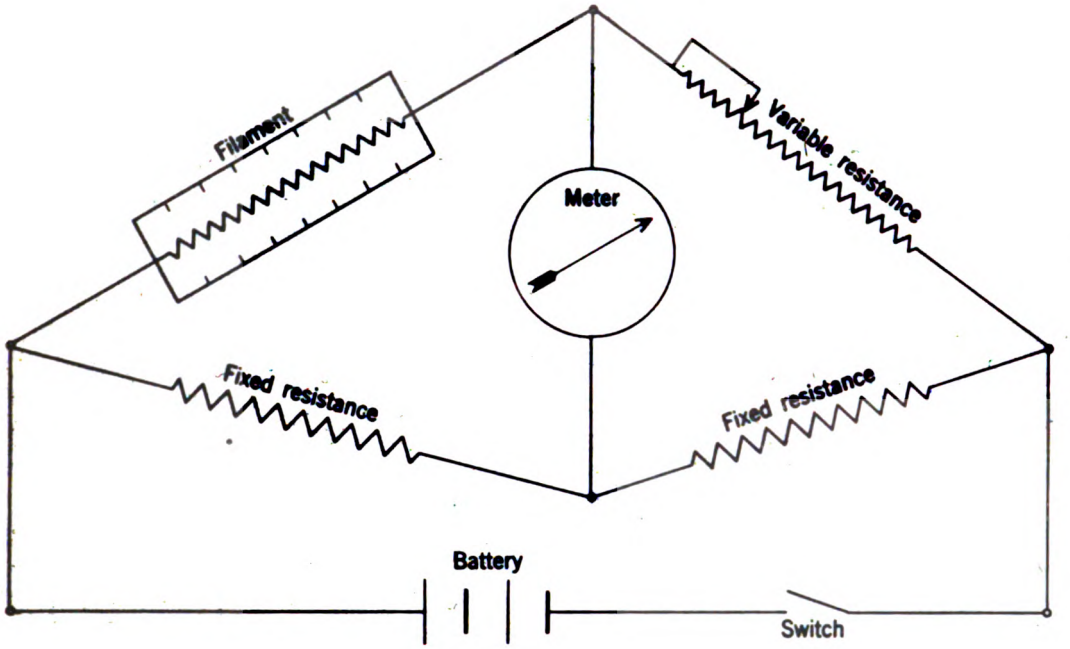
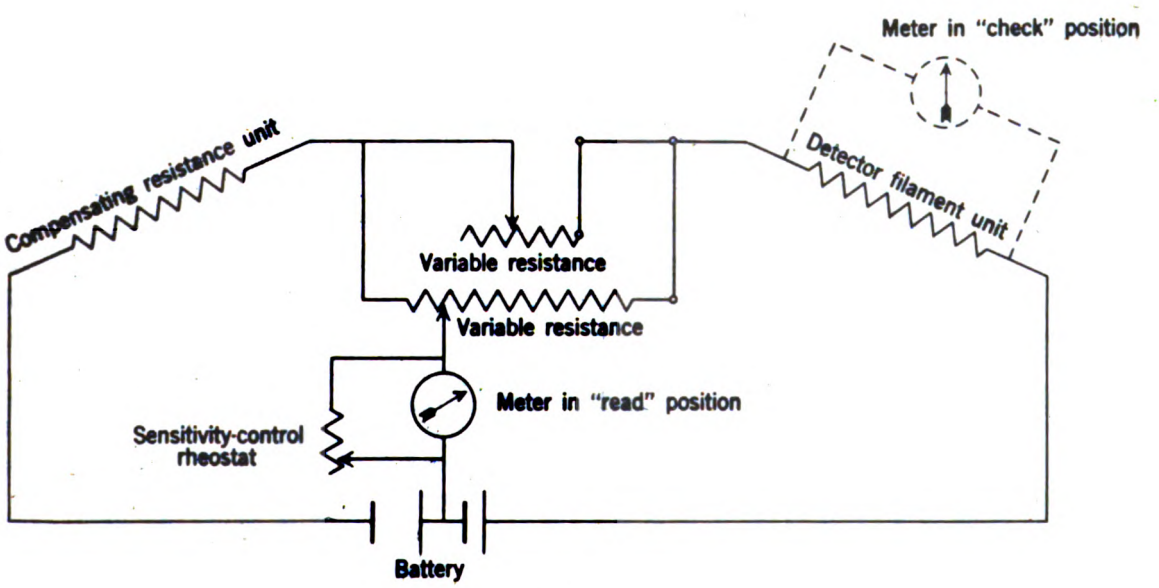


U.C.C. DETECTOR CIRCUIT



M.S.A. DETECTOR CIRCUIT

Figure 3.– Electric circuits of the U.C.C. and M.S.A. methane-indicating detectors.

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The first large company whose mines were sampled by the Bureau of Mines had equipped its ventilation inspector with a U.C.C. detector, which he carried during the sampling of the airways of all their mines. The results obtained with this instrument, the immediate determinations of methane percentage obtained, and the opportunity for making an exhaustive study of the practicability of the instrument led the Bureau to provide the writer with one for use during the rest of the sampling.

The results of analysis of samples collected by the Bureau of Mines and the readings of the U.C.C. methane-indicating detector are given in table 1.

TABLE 1. - Comparison of U.C.C.-Detector Readings with Analyses by Haldane Method

Type of sample	Methane, percent, by -		Difference		Methane per 24 hours, cubic feet
	Analysis	Detector	+	-	
Main return	0.12	0.05		0.07	312,000
Do.	.15	.10		.05	312,000
Do.	.30	.20		.10	880,000
Do.	.30	.20		.10	880,000
Do.	.39	.40	0.01		1,250,000
Do.	.38	.40	.02		1,250,000
Do.	.19	.11		.08	253,900
Do.	.19	.11		.08	253,900
Do.	.37	.40	.03		1,190,000
Do.	.37	.40	.03		1,190,000
Do.	.12	.15	.07		577,000
Do.	.15	.15	.00	.00	577,000
Do.	.03	.02		.01	52,500
Do.	.03	.02	.00	.00	52,500
Do.	.28	.32	.04		859,000
Do.	.28	.32	.04		859,000
Do.	.39	.35		.04	852,000
Do.	.38	.35		.03	852,000
Do.	.62	.60		.02	2,700,000
Do.	.62	.60		.02	2,700,000
Do.	.16	.20	.04		480,000
Do.	.15	.20	.05		480,000
Do.	.31	.38	.07		1,485,000
Do.	.32	.38	.06		1,485,000
Do.	.15	.10		.05	598,000
Do.	.15	.10		.05	598,000
Do.	.44	.40		.04	2,675,000
Do.	.46	.40		.06	2,675,000
Do.	.26	.21		.05	882,500
Do.	.24	.21		.03	882,500

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TABLE 1. - Comparison of U.C.C.-Detector Readings with Analyses by Haldane Method (Continued)

Type of sample	Methane, percent, by - Analysis	Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Main Return	0.86	0.85		0.01	2,080,000
Do.	.88	.85		.03	2,080,000
Do.	.47	.50	0.03		1,979,000
Do.	.50	.50	.00	.00	1,979,000
Do.	.61	.60		.01	2,330,000
Do.	.60	.60	.00	.00	2,330,000
Do.	.37	.32		.05	620,000
Do.	.34	.32		.02	620,000
Do.	.04	.05	.01		90,250
Do.	.04	.05	.01		90,250
Do.	.06	.05		.01	106,500
Do.	.08	.05		.03	106,500
Do.	.09	.08		.01	266,000
Do.	.08	.08	Exact		266,000
Do.	.93	1.05	.12		1,892,000
Do.	.83	1.05	.22		1,892,000
Do.	.02	.00		.02	11,550
Do.	.02	.00		.02	11,550
Do.	.24	.35	.11		258,000
Do.	.24	.35	.11		258,000
Return from split	.34	.60	.26		268,000
Do.	.35	.60	.25		268,000
Do.	.21	.30	.09		161,500
Do.	.22	.30	.08		161,500
Do.	.24	.25	.01		159,500
Do.	.24	.25	.01		159,500
Do.	.11	.00		.11	50,000
Do.	.12	.00		.12	55,000
Do.	.20	.12		.08	59,300
Do.	.19	.12		.07	59,300
Do.	.27	.10		.17	109,800
Do.	.27	.10		.17	109,800
Do.	.29	.25		.04	257,500
Do.	.27	.25		.02	257,500
Do.	.35	.30		.05	143,800
Do.	.33	.30		.03	143,800
Main Return	.21	.10		.11	1,091,000
Do.	.21	.10		.11	1,091,000
Return from split	.33	.32		.01	1,011,000
Do.	.37	.32		.05	1,011,000

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TABLE 1. - Comparison of U.C.C.-Detector Readings with Analyses by Haldane Method (Continued)

Type of sample	Methane, percent, by - Analysis	Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Return from split	0.02	0.10	0.08		3,295
Do.	.15	.15	Exact		47,400
Do.	.15	.15	do		47,400
Do.	.25	.21		0.04	160,500
Do.	.24	.21		.03	160,500
Do.	.10	.05		.05	88,600
Do.	.11	.05		.06	88,600
Do.	.13	.15	.02		96,800
Do.	.13	.15	.02		96,800
Main return	.00	.00	Exact		--------
Do.	.00	.00	Exact		--------
Do.	.04	.00		.03	32,300
Do.	.03	.00		.02	24,200
Return from split	20.6	Explosive mixture			--------
Do.	15.4	do			--------
Do.	2.23	2.00		.23	--------
Do.	2.06	2.00		.06	--------
Main return	.30	.30	Exact		254,000
Do.	.26	.30	.04		250,000
Do.	.08	.15	.07		188,946
Do.	.31	.40	.09		493,000
Do.	.11	.15	.04		305,000
Return from split	.00	.02	.02		--------
Do.	.00	.02	.02		--------
Do.	.15	.20	.05		203,000
Do.	.12	.12	Exact		10,500
Do.	.04	.15	.11		50,600
Do.	.00	.00	Exact		--------
Do.	.03	.05	.02		7,590
Do.	.00	.05	.05		--------
Do.	.00	.05	.05		--------
Do.	.03	.03			10,600
Do.	.02	.00		.02	5,450
Main return	.00	.10	.10		--------
Do.	.02	.10	.08		--------
Do.	.14	.30	.16		311,500
Do.	.15	.35	.20		311,500
Do.	.32	.18		.14	372,000
Do.	.30	.19		.11	372,000
Do.	.00	.02	.02		5,640

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TABLE 1. - Comparison of U.C.C.-Detector Readings with Analyses by Haldane Method (Continued)

Type of sample	Methane, percent, by - Analysis	Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Main return	0.01	0.03	0.02		5,640
Return from split	.01	.00		0.01	--------
Main return	.00	.00	Exact		--------
Do.	.02	.00		.02	17,280
Do.	.04	.00		.04	17,280
Do.	.01	.05	.04		7,540
Do.	.00	.00	Exact		--------
Do.	.00	.00	do		--------
Do.	.01	.00		.01	20,925
Do.	.02	.00		.02	20,925
Do.	.02	.00		.02	47,300
Do.	.04	.00		.04	47,300
Do.	.02	.02	Exact		13,750
Do.	.02	.02	do		13,750
Do.	.01	.00		.01	3,940
Do.	.01	.00		.01	3,940
Do.	.08	.10	.02		43,500
Do.	.07	.10	.03		43,500
Return from split	.00	.00	Exact		--------
Do.	.00	.00	do		--------
Main return	.00	.10	.10		--------
Do.	.00	.10	.10		--------
Return from split	.17	.15		.02	347,000
Do.	.18	.15		.03	347,000
Do.	.00	.08	.08		--------
Do.	.00	.08	.08		--------
Do.	.29	.28		.01	285,000
Do.	.29	.28		.01	285,000
Main return	.01	.05	.04		18,300
Do.	.00	.05	.05		18,300
Return from split	.01	.10	.09		19,100
Do.	.01	.10	.09		19,100
Main return	.00	.00	Exact		--------
Do.	.00	.00	do		--------
Do.	.02	.07	.05		19,290
Do.	.02	.05	.03		19,290
Do.	.03	.05	.02		33,000
Do.	.02	.05	.03		33,000
Do.	.08	.10	.02		167,000
Do.	.09	.10	.01		167,000

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TABLE 1. - Comparison of U.C.C.-Detector Readings with Analyses by Haldane Method (Continued)

Type of sample	Methane, percent, by - Analysis	Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Main return	0.03	0.10	0.07		43,800
Do.	.03	.10	.07		43,800
Do.	.00	.05	.05		35,700
Do.	.03	.05	.02		35,700
Do.	.01	.00		0.01	32,400
Do.	.02	.00		.02	32,400
Face sample	.03	.02		.01	--------
Do.	.04	.02		.01	--------
Return from split	.00	.00	Exact		--------
Do.	.00	.00	do.		--------
Do.	.02	.10	.08		1,615
Do.	.03	.10	.07		1,615
Do.	.04	.00		.03	9,370
Do.	.02	.00		.02	9,370
Do.	.14	.00		.14	51,100
Do.	.14	.00		.14	51,100
Do.	.14	.00		.14	185,000
Do.	.16	.00		.16	185,000
Do.	.08	.00		.08	31,600
Do.	.08	.00		.08	31,600
Main return	.08	.00		.08	111,700
Do.	.06	.00		.06	111,700
Do.	.04	.00		.04	61,500
Do.	.05	.00		.05	61,500
Return from split	.07	.00		.07	41,000
Do.	.06	.00		.06	41,000
Do.	.56	.50		.06	105,500
Do.	.57	.50		.07	105,500
Do.	.35	.40	.05		26,400
Do.	.35	.40	.05		26,400
Do.	.37	.40	.03		157,200
Do.	.38	.40	.02		157,200
Do.	.45	.50	.05		114,200
Do.	.41	.50	.09		114,200
Do.	.11	.10		.01	48,700
Do.	.12	.10		.02	48,700
Main return	.04	.10	.06		32,400
Do.	.03	.10	.07		32,400
Do.	.04	.00		.04	59,900
Do.	.05	.00		.05	59,900

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TABLE 1. - Comparison of U.C.C.-Detector Readings with Analyses by Haldane Method (Continued)

Type of sample	Methane, percent, by - Analysis	Methane, percent, by - Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Return from split	0.04	0.05	0.01		4,960
Do.	.05	.05	Exact		4,960
Do.	.04	.00		0.04	20,500
Do.	.04	.00		.04	20,500
Do.	.11	.10		.01	84,400
Do.	.10	.10	Exact		84,400
Do.	.12	.10		.02	279,800
Do.	.12	.10		.02	279,800
Do.	.04	.00		.04	65,600
Do.	.04	.00		.04	65,600
Do.	.08	.10	.02		84,000
Do.	.09	.10	.01		112,200
Do.	.08	.10	.02		26,780
Do.	.06	.10	.04		26,780
Do.	.06	.00		.06	19,500
Do.	.05	.00		.05	19,500
Do.	.03	.00		.03	14,450
Do.	.02	.00		.02	14,450
Do.	.11	.00		.11	32,900
Do.	.10	.00		.10	32,900
Do.	.02	.10	.08		30,280
Do.	.04	.10	.06		30,280
Do.	.03	.05	.02		23,190
Do.	.07	.10	.03		25,600
Do.	.07	.00		.07	33,200
Do.	.09	.00		.09	33,200
Do.	.02	.10	.08		10,450
Do.	.03	.10	.07		10,450
Do.	.02	.00		.02	5,260
Do.	.02	.00		.02	5,260
Do.	.00	.15	.15		3,345
Do.	.01	.15	.14		3,345
Do.	.03	.10	.07		8,680
Do.	.02	.10	.08		8,680
Do.	.07	.10	.03		48,100
Do.	.10	.10	Exact		48,100
Do.	.14	.10		.04	140,800
Do.	.15	.10		.05	140,800
Do.	.16	.25	.09		121,000
Do.	.17	.25	.08		121,000

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TABLE 1. - Comparison of U.C.C.-Detector Readings with Analyses by Haldane Method (Continued)

Type of sample	Methane, percent, by - Analysis	Methane, percent, by - Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Return from split	0.06	0.25	0.19		44,000
Do.	.04	.25	.21		44,000
Main return	.04	.15	.11		31,700
Do.	.04	.15	.11		31,700
Return from split	.12	.10		0.02	42,800
Do.	.09	.10	.01		42,800
Do.	.03	.00		.03	11,000
Do.	.03	.00		.03	11,000
Do.	.03	.00		.03	5,920
Do.	.03	.00		.03	5,920
Do.	.02	.00		.02	23,600
Do.	.01	.00		.01	23,600
Do.	.15	.10		.05	159,000
Do.	.16	.10		.06	159,000
Do.	.00	.00	Exact		---------
Do.	.00	.00	do.		---------
Do.	.03	.00		.03	5,250
Do.	.01	.00		.01	5,250
Do.	.18	.22	.04		164,000
Do.	.16	.22	.06		164,000
Do.	.04	.00		.04	31,600
Do.	.03	.00		.03	31,600
Do.	.05	.00		.05	118,000
Do.	.07	.00		.07	118,000
Do.	.00	.00	Exact		4,300
Do.	.01	.00		.01	4,300
Do.	.03	.05	.02		1,660
Do.	.02	.05	.03		1,660
Do.	.03	.00		.03	14,950
Do.	.05	.00		.05	14,950
Main return	.05	.10	.05		54,250
Do.	.04	.10	.06		54,250
Do.	.51	.35		.16	218,000
Do.	.50	.35		.15	218,000
Do.	.13	.05		.08	120,000
Do.	.12	.05		.07	120,000
Do.	.24	.25	.01		270,000
Do.	.26	.25		.01	270,000
Do.	.18	.20	.02		400,000
Do.	.19	.20	.01		400,000

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TABLE 1. - Comparison of U.C.C.-Detector Readings with Analyses by Haldane Method (Continued)

Type of sample	Methane, percent, by - Analysis	Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Main return	0.06	0.10	0.04		99,500
Do.	.09	.10	.01		99,500
Do.	.25	.30	.05		697,000
Do.	.25	.30	.05		697,000
Do.	.12	.25	.13		143,000
Do.	.12	.25	.13		143,000
Do.	.41	.50	.09		685,000
Do.	.22	.20		0.02	400,000
Do.	.22	.20		.02	400,000
Do.	.05	.15	.10		43,300
Do.	.10	.15	.05		121,000
Do.	.03	.05	.02		24,900
Return from split	.00	.00	Exact		--------
Do.	.00	.00	do.		--------
Main return	.16	.00		.16	423,000
Do.	.15	.00		.15	396,000
Face sample	.03	.00		.03	44,500
Do.	.03	.00		.03	44,500
Return from split	.00	.00	Exact		--------
Do.	.00	.00	do.		--------
Do.	.03	.10	.07		2,130
Do.	.05	.10	.05		2,130
Do.	.07	.10	.03		2,290
Do.	.08	.10	.02		2,290
Do.	.06	.13	.07		5,225
Do.	.06	.13	.07		5,225
Do.	.10	.10	Exact		4,980
Do.	.10	.10	do.		4,980
Main return	.06	.20	.14		67,500
Do.	.05	.20	.15		67,500
Do.	.36	.15		.21	687,000
Do.	.35	.15		.20	687,000
Return from split	.20	.20	Exact		34,200
Do.	.20	.20	do.		34,200
Do.	.14	.20	.06		14,700
Do.	.13	.20	.07		14,700
Main return	.07	.20	.13		91,100
Do.	.08	.20	.12		91,100
Do.	.15	.15	Exact		169,900
Do.	.15	.15	do.		169,900

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TABLE 1. - Comparison of U.C.C.-Detector Readings with Analyses by Haldane Method (Concluded)

Type of sample	Methane, percent, by - Analysis	Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Return from split	0.06	0.15	0.09		1,985
Do.	.06	.15	.09		1,985
Do.	.41	.35		0.06	49,800
Do.	.40	.35		.05	49,800
Do.	.50	.55	.05		372,000
Do.	.35	.30		.05	278,500
Do.	.37	.30		.07	278,500
Do.	.03	.00		.03	7,580
Main return	.20	.15		.05	123,500
Do.	.76	.75		.01	589,000
Do.	.11	.10		.01	475,000
Do.	.15	.10		.05	475,000
Do.	.08	.05		.03	135,000
Do.	.10	.05		.05	135,000
Do.	.19	.10		.09	236,500
Do.	.21	.10		.11	236,500

Number of comparisons	323[1]
Number of high readings (+)	132
Number of low readings (-)	152
Number of exact readings	39
Average variation in high readings	0.065
Average variation in low readings	.053
Average variation in all readings, disregarding signs	.051
Maximum percentage methane (by analysis)	2.23
Average percentage methane (by analysis)	.15

[1] Does not include two samples above the range of the detector.

In January 1933 the writer was provided with an M.S.A. detector which was used in sampling return airways of 79 mines; results of these tests are compared with laboratory analyses in table 2.

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TABLE 2. - Comparison of M.S.A.-Detector Readings with Analyses by Haldane Method

Type of sample	Methane, percent, by - Analysis	Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Return from split	0.20	0.15		0.05	34,200
Do.	.47	.35		.12	97,200
Main return	1.24	1.10		.14	2,564,640
Do.	1.25	1.10		.15	2,564,640
Do.	.25	.26	0.01		193,000
Do.	.24	.26	.02		193,000
Return from split	.14	.15	.01		15,250
Do.	1.50	1.20		.30	1,510,000
Main return	.04	.05	.01		23,350
Do.	.02	.05	.03		23,350
Return from split	.01	.02	.01		720
Do.	.01	.02	.01		720
Main return	.01	.00		.01	6,912
Do.	.01	.00		.01	6,912
Do.	.02	.06	.04		16,900
Do.	.00	.06	.06		16,900
Do.	.02	.00		.02	2,000
Do.	.01	.00		.01	1,000
Do.	.00	.05	.05		--------
Do.	.00	.05	.05		--------
Return from split	.00	.07	.07		--------
Do.	.00	.07	.07		--------
Do.	.06	.10	.04		5,190
Do.	.06	.10	.04		5,190
Do.	.44	.50	.06		31,500
Do.	.47	.50	.03		31,500
Main return	.04	.05	.01		131,000
Do.	.04	.05	.01		131,000
Return from split	.16	.28	.12		266,112
Do.	.17	.28	.11		266,112
Main return	.40	.38		.02	1,040,000
Do.	.40	.38		.02	1,040,000
Do.	.55	.52		.03	1,181,000
Do.	.52	.52	Exact		1,181,000
Do.	.06	.10	.04		102,500
Do.	.04	.10	.06		102,500
Do.	.00	.05	.05		--------
Do.	.00	.05	.05		--------
Do.	.07	.07	Exact		223,800
Do.	.06	.07	.01		223,800

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TABLE 2. – Comparison of M.S.A.-Detector Readings with Analyses By Haldane Method (Continued)

Type of sample	Methane, percent, by – Analysis	Detector	Difference +	Difference –	Methane per 24 hours, cubic feet
Main return	0.42	0.39		0.03	1,149,630
Do.	.40	.39		.01	1,149,630
Do.	.40	.47	0.07		1,035,000
Do.	.41	.44	.03		1,035,000
Do.	.35	.34		.01	692,000
Do.	.36	.34		.02	692,000
Do.	.27	.26		.01	796,000
Do.	.25	.26	.01		796,000
Do.	.04	.05	.01		61,200
Do.	.02	.05	.03		61,200
Do.	.01	.00		.01	2,810
Do.	.00	.00	Exact		--------
Do.	.00	.02	.02		--------
Do.	.00	.02	.02		--------
Do.	.02	.00		.02	33,840
Do.	.00	.00	Exact		--------
Do.	.02	.02	do.		4,960
Do.	.00	.02	.02		--------
Do.	.02	.05	.03		27,500
Do.	.02	.05	.03		27,500
Do.	.38	.60	.22		188,500
Do.	.37	.60	.23		188,500
Return from split	.65	.50		.15	85,000
Do.	.68	.50		.18	85,000
Do.	.64	.45		.19	87,500
Do.	.63	.45		.18	87,500
Do.	.02	.04	.02		1,094
Do.	.02	.04	.02		1,094
Do.	.02	.05	.03		542
Do.	.02	.05	.03		542
Do.	.02	.05	.03		1,345
Do.	.02	.05	.03		1,345
Do.	.03	.02		.01	984
Do.	.02	.02	Exact		984
Do.	.02	.05	.03		1,820
Do.	.02	.05	.03		1,820
Main return	.17	.18	.01		60,000
Do.	.18	.18	Exact		60,000
Return from split	.02	.05	.03		34,900
Do.	.03	.05	.02		34,900

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TABLE 2. - Comparison of M.S.A.-Detector Readings with Analyses By Haldane Method (Continued)

Type of sample	Methane, percent, by - Analysis	Methane, percent, by - Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Return from split	0.03	0.04	0.01		29,900
Do.	.03	.04	.01		29,900
Do.	.01	.00		0.01	2,540
Do.	.00	.00	Exact		--------
Main return	.02	.00		.02	5,600
Do.	.03	.00		.03	5,600
Do.	.03	.05	.02		4,100
Do.	.01	.05	.04		4,100
Do.	.02	.05	.03		7,260
Do.	.01	.05	.04		7,260
Do.	.02	.09	.07		3,840
Do.	.02	.09	.07		3,840
Do.	.01	.02	.01		4,457
Do.	.02	.02	Exact		4,457
Do.	.00	.00	do.		--------
Do.	.00	.00	do.		--------
Do.	.00	.00	do.		--------
Do.	.00	.05	.05		--------
Do.	.00	.05	.05		--------
Return from split	.00	.08	.08		--------
Do.	.00	.08	.08		--------
Do.	.00	.05	.05		--------
Do.	.00	.05	.05		--------
Do.	.19	.20	.01		148,853
Do.	.18	.15		.03	87,091
Main return	.09	.05		.04	96,941
Do.	.13	.05		.08	96,941
Return from split	.55	.40		.15	--------
Do.	.57	.40		.17	--------
Main return	.04	.10	.06		8,864
Do.	.02	.10	.08		8,864
Return from split	.19	.14		.05	18,147
Do.	.04	.09	.05		7,354
Do.	.10	.12	.02		5,766
Do.	.02	.10	.08		--------
Main return	.05	.05	Exact		95,644
Do.	.05	.05	do.		95,644
Do.	.11	.10		.01	181,500
Do.	.12	.10		.02	181,500

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TABLE 2. - Comparison of M.S.A.-Detector Readings with Analyses By Haldane Method (Continued)

Type of sample	Methane, percent, by - Analysis	Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Return from split	0.09	0.08		0.01	135,823
Do.	.09	.08		.01	135,823
Do.	.09	.14	0.05		--------
Do.	.19	.25	.06		70,225
Do.	.12	.07		.05	4,095
Do.	.13	.07		.06	4,095
Main return	.04	.07	.03		143,586
Do.	.04	.07	.03		143,586
Return from split	.05	.04		.01	12,549
Do.	.13	.10		.03	24,124
Do.	.05	.05	Exact		16,236
Do.	.03	.00		.03	--------
Do.	.06	.05		.01	5,654
Do.	.02	.00	.02		2,677
Main return	.00	.00	Exact		--------
Do.	.00	.00	do.		--------
Return from split	.00	.00	do.		--------
Do.	.00	.00	do.		--------
Do.	.00	.00	do.		--------
Do.	.00	.00	do.		--------
Main return	.00	.01	.01		--------
Do.	.00	.01	.01		--------
Do.	.01	.01	Exact		9,800
Do.	.00	.01	.01		--------
Do.	.02	.00		.02	16,390
Do.	.02	.00		.02	16,390
Return from split	.05	.00		.05	19,500
Do.	.05	.00		.05	19,500
Main return	.05	.00		.05	12,000
Do.	.03	.00		.03	10,790
Do.	.03	.00		.03	26,000
Do.	.03	.00		.03	26,000
Do.	.02	.00		.02	2,160
Do.	.02	.00		.02	2,160
Do.	.00	.00	Exact		--------
Do.	.00	.00	do.		--------
Return from split	.00	.00	do.		--------
Do.	.00	.00	do.		--------
Do.	.00	.00	do.		--------
Do.	.00	.00	do.		--------

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TABLE 2. - Comparison of M.S.A.-Detector Readings with Analyses By Haldane Method (Continued)

Type of sample	Methane, percent, by - Analysis	Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Main return	0.02	0.05	0.03		8,294
Do.	.01	.05	.04		8,294
Return from split	.00	.00	Exact		----------
Do.	.01	.00		0.01	----------
Do.	.01	.02	.01		318
Do.	.01	.02	.01		318
Do.	.07	.08	.01		4,977
Do.	.05	.08	.03		4,977
Main return	.00	.03	.03		----------
Do.	.00	.03	.03		----------
Face sample	.16	.19	.03		----------
Do.	.14	.12		.02	----------
Main return	.06	.05		.01	21,200
Do.	.06	.05		.01	21,200
Do.	.08	.15	.07		13,450
Do.	.08	.15	.07		13,450
Face sample	.00	.02	.02		----------
Do.	.02	.05	.03		----------
Main return	.03	.02		.01	56,400
Do.	.01	.02	.01		56,400
Face sample	.00	.00	Exact		----------
Do.	.00	.00	do.		----------
Do.	.08	.08	do.		----------
Do.	.04	.00		.04	----------
Main return	.01	.04	.03		1,680
Do.	.01	.04	.03		1,680
Do.	.02	.03	.01		4,860
Do.	.01	.03	.02		4,860
Face sample	.00	.02	.02		----------
Return from split	.00	.03	.03		----------
Do.	.02	.03	.01		3,150
Main return	.02	.02	Exact		4,300
Do.	.02	.02	do.		4,300
Do.	.00	.04	.04		----------
Do.	.00	.04	.04		----------
Return from split	.00	.02	.02		----------
Do.	.00	.02	.02		----------
Do.	.02	.03	.01		162
Do.	.01	.03	.02		162

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TABLE 2. - Comparison of M.S.A.-Detector Readings with Analyses By Haldane Method (Continued)

Type of sample	Methane, percent, by - Analysis	Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Return from split	0.29	0.30	0.01		232,000
Do.	.31	.30		0.01	232,000
Do.	.13	.15	.02		39,100
Do.	.23	.25	.02		94,400
Do.	.05	.05	Exact		7,800
Do.	.04	.05	.01		7,800
Do.	.16	.15		.01	78,200
Do.	.10	.15	.05		78,200
Do.	.05	.06	.01		26,300
Do.	.05	.06	.01		26,300
Face sample	.12	.13	.01		--------
Do.	.12	.13	.01		--------
Main return	.45	.43		.02	657,000
Do.	.45	.43		.02	657,000
Do.	.18	.20	.02		435,000
Do.	.17	.20	.03		435,000
Return from split	.03	.11	.08		29,900
Do.	.05	.11	.06		29,900
Do.	.10	.14	.04		82,500
Do.	.10	.14	.04		82,500
Main return	.06	.10	.04		79,250
Do.	.05	.10	.05		79,250
Do.	.06	.15	.09		172,900
Do.	.06	.15	.09		172,900
Do.	.03	.04	.01		85,700
Do.	.04	.04	Exact		85,700
Do.	.02	.10	.08		51,800
Do.	.01	.10	.09		51,800
Return from split	.01	.05	.04		650
Do.	.01	.05	.04		650
Do.	.01	.06	.05		1,495
Do.	.01	.06	.05		1,495
Do.	.01	.11	.10		1,535
Do.	.02	.11	.09		1,535
Do.	.33	.33	Exact		381,000
Do.	.33	.33	do.		381,000
Do.	.05	.05	do.		28,400
Do.	.03	.05	.02		28,400
Do.	.05	.15	.10		6,500
Do.	.04	.15	.11		6,500

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TABLE 2. - Comparison of M.S.A.-Detector Readings with Analyses By Haldane Method (Continued)

Type of sample	Methane, percent, by - Analysis	Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Main return	0.03	0.03	Exact		45,410
Return from split	.05	.02		.03	37,400
Do.	.06	.02		.04	37,400
Main return	.11	.04		.07	238,000
Do.	.12	.04		.08	238,000
Do.	.01	.00		.01	17,500
Do.	.01	.00		.01	17,500
Return from split	.00	.01	.01		-------
Do.	.01	.01	Exact		173
Do.	.01	.05	.04		-------
Do.	.02	.05	.03		-------
Do.	.02	.01		.01	168
Do.	.01	.01	Exact		168
Do.	.06	.06	do.		13,793
Do.	.06	.06	do.		13,793
Main return	.01	.02	.01		3,970
Do.	.03	.02		.01	3,970
Do.	.02	.05	.03		8,840
Do.	.03	.05	.02		8,840
Return from split	1.51	1.35		.16	26,200
Do.	1.52	1.35		.17	26,200
Do.	.05	.10	.05		-------
Do.	.05	.10	.05		-------
Do.	.05	.10	.05		5,310
Do.	.05	.10	.05		5,310
Do.	.03	.10	.07		1,290
Do.	.02	.10	.08		1,290
Main return	.03	.00		.03	62,400
Do.	.03	.00		.03	62,400
Do.	.02	.05	.03		35,700
Do.	.05	.05	Exact		35,700
Do.	.04	.05	.01		72,400
Do.	.04	.05	.01		72,400
Do.	.02	.10	.08		28,800
Do.	.02	.10	.08		28,800
Do.	.05	.15	.10		110,500
Do.	.06	.15	.09		110,500
Do.	.02	.10	.08		36,000
Do.	.03	.10	.07		36,000
Return from split	.13	.10		.03	-------
Do.	.12	.10		.02	-------

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TABLE 2. - Comparison of M.S.A.-Detector Readings with Analyses By Haldane Method (Continued)

Type of sample	Methane, percent, by - Analysis	Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Return from split	0.03	0.00		0.03	--------
Do.	.01	.00		.01	--------
Main return	.01	.00		.01	2,900
Do.	.01	.00		.01	2,900
Do.	.22	.15		.07	55,000
Do.	.22	.15		.07	55,000
Do.	.03	.05	0.02		287,239
Do.	.04	.05	.01		287,239
Do.	.04	.05	.01		188,326
Do.	.03	.05	.02		188,326
Do.	.14	.10		.04	115,200
Do.	.13	.10		.03	115,200
Do.	.20	.20	Exact		394,000
Do.	.20	.20	do.		394,000
Do.	.03	.05	.02		44,500
Do.	.03	.04	.01		17,900
Return from split	.02	.02	Exact		6,620
Do.	.02	.02	do.		6,620
Main return	.05	.05	do.		59,700
Do.	.04	.05	.01		6,700
Do.	.00	.02	.02		--------
Do.	.01	.02	.01		--------
Do.	.02	.02	Exact		--------
Do.	.01	.02	.01		--------
Repeat sample	.01	.00		.01	--------
Do.	.01	.00		.01	--------
Main return	.06	.10	.04		71,700
Do.	.06	.10	.04		71,700
Do.	.06	.10	.04		40,500
Do.	.07	.10	.03		47,300
Do.	.08	.15	.07		91,200
Do.	.08	.15	.07		91,200
Return from split	.03	.06	.03		6,550
Do.	.03	.06	.03		6,550
Do.	.02	.02	Exact		3,790
Do.	.00	.02	.02		3,790
Do.	.01	.03	.02		927
Do.	.05	.00		.05	9,161
Do.	.01	.03	.02		--------
Do.	.05	.05	Exact		5,637

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TABLE 2. - Comparison of M.S.A.-Detector Readings with Analyses By Haldane Method (Continued)

Type of sample	Methane, percent, by - Analysis	Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Return from split	0.04	0.00		0.04	9,266
Main return	.27	.16		.11	903,753
Do.	.24	.16		.08	903,753
Do.	.03	.02		.01	2,923
Do.	.05	.02		.03	2,923
Do.	.00	.01	0.01		4,246
Do.	.01	.01	Exact		4,246
Do.	.00	.00	do.		--------
Do.	.00	.00	do.		--------
Do.	.04	.00		.04	17,110
Do.	.04	.00		.04	17,110
Return from split	.03	.04	.01		30,142
Do.	.04	.04	Exact		30,142
Do.	.02	.05	.03		2,442
Do.	.02	.05	.03		2,442
Do.	.80	.80	Exact		22,778
Do.	.78	.80	.02		22,778
Main return	.04	.00		.04	12,530
Do.	.02	.00		.02	12,530
Do.	.00	.00	Exact		--------
Do.	.00	.00	do.		--------
Do.	.03	.03	do.		36,450
Do.	.02	.03	.01		36,450
Return from split	.02	.05	.03		12,040
Do.	.02	.05	.03		12,040
Do.	.01	.05	.04		2,407
Do.	.00	.05	.05		2,407
Main return	.00	.00	Exact		--------
Do.	.00	.00	do.		--------
Do.	.00	.00	do.		--------
Do.	.01	.00		.01	1,260
Return from split	.00	.03	.03		--------
Do.	.00	.03	.03		--------
Do.	.00	.02	.02		--------
Do.	.00	.02	.02		--------
Main return	.00	.03	.03		--------
Do.	.01	.03	.02		--------
Return from split	.00	.00	Exact		--------
Do.	.00	.00	do.		--------

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TABLE 2. - Comparison of M.S.A.-Detector Readings with Analyses By Haldane Method (Concluded)

Type of sample	Methane, percent, by - Analysis	Detector	Difference +	Difference -	Methane per 24 hours, cubic feet
Return from split	0.00	0.00	Exact		--------
Do.	.00	.00	do.		--------
Do.	.00	.00	do.		--------
Do.	.00	.00	do.		--------
Main return	.00	.00	do.		--------
Do.	.00	.00	do.		--------

Number of comparisons	364
Number of high readings (+)	194
Number of low readings (-)	98
Number of exact readings	72
Average variation in high readings	0.038
Average variation in low readings	.045
Average variation in all readings, disregarding signs	.032
Maximum percentage methane (by analysis)	1.52
Average percentage methane (by analysis)	.096

Every reasonable effort was made to follow the instructions of the manufacturers in caring for the instruments, including charging and caring for the batteries, except that whenever the opportunity presented itself both instruments were demonstrated to mine officials by gasoline fumes or acetylene gas when no methane was available for the purpose.

Some of the important practical aspects of the results obtained, life of the parts, and reactions of the user are given in table 3 for comparison:

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TABLE 3. - Comparison of U.C.C. and M.S.A. methane detectors

	U.C.C. Detector	M.S.A. Detector
Weight and distribution	10¼ pounds; well distributed.	16¼ pounds; poorly distributed.
Maximum weight of any one part	6½ pounds; battery.	10½ pounds; meter case.
Accuracy in practice, average variation	0.05	0.032
Practicability for mine use	Good.	Good.
Life of filaments	Relatively short.	Relatively long.
Light from attached cap lamp	Poor.	Good.
Life of battery per charge in practice	5 hours.	5 hours.
Difficulties with batteries	Short life; requires strict care.	Corrosion in "K" model.
Difficulties with other parts	None.	Blocking of orifices in air circuit.

DIFFICULTIES ENCOUNTERED AND HOW CORRECTED

The numerous difficulties that may be encountered through failure to follow the manufacturers instructions for use and care of the detectors are not discussed because it is assumed that these instructions will be followed as carefully by other users of detectors as they were in these tests.

The work presented a few difficulties that undoubtedly caused the readings to vary more than they should have:

M.S.A. detector:

1. Corrosion of terminals and leads.
2. Blocking of orifices.
3. Packing of glass wool in drier tube.
4. Oxidation of rheostat and switches.

U.C.C. detector:

1. Poor illumination from cap lamp.
2. Inability to check zero setting in different mines.
3. Relatively short life of filaments.

These difficulties are overcome readily when the user recognizes them but at first may cause errors in readings that will affect the results.

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M.S.A. Detector

1. It was found that the Model "K" Edison cap-lamp batteries used with the detector and with the cap lamps only corrode to a greater extent than the older-type Edison batteries. This difficulty was overcome by thoroughly cleaning the cells, container, and rubber sacks and applying a coat of liquid rubber cement to the tops of the cells and around the edges of the rubber sacks.

2. Blocking of any of the orifices or any other part of the air-sampling circuit may cause a wide variation in methane indication; in practice this did not occur frequently. The difficulty is apparent when the meter shows an indication of methane in strictly fresh air. The air-flow sample is closely controlled by small orifices at the intake and exhaust ends of the sampling circuit, both of which must be clean, but care must be taken not to enlarge the openings in cleaning them.

3. Blocking occurs generally at the bottom of the drier tube where the glass wool packs too tightly on the screen, or calcium chloride dust cakes on the screen; this can be remedied by removing the glass wool occasionally, fluffing it out, and making sure that the screen is clean and the calcium chloride is in good condition.

4. An oxide coating on rheostat and switch contacts affects the flow of electric current through the circuit materially. This difficulty is experienced only when the instrument has been idle for several days; it can be overcome readily by operating the switches and rheostats back and forth several times to polish their surfaces.

U.C.C. Detector

1. The poor illumination from the U.C.C. cap-lamp attachment is inherent in the design and probably can be overcome only by carrying an additional permissible cap lamp or a permissible flashlight.

2. The inability to check zero readings in the mines visited is also inherent in the design of the equipment. Strictly fresh air, or at least air absolutely free from combustible gas, must be available if accurate readings are to be obtained with this apparatus; if this condition is lacking close approximations may be made provided the percentage of methane in certain airways is known and is used as a standard for setting the instrument. In the sampling described in this report neither of these conditions prevailed at times, and some of the results therefore varied rather widely.

3. The life of the filament depends chiefly on the length of time it is used per day and the percentage of methane encountered. As the filament is subjected constantly to increased temperature during travel in return airways containing methane it is advisable when possible to shut off the detector after taking a reading, provided a check location can be found for setting the instrument for the next reading. Spare filaments should be carried dur-

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ing inspection trips underground; they can be changed readily, but a new zero setting must be made after a change of filaments.

CONCLUSION

The high degree of accuracy of these permissible methane-indicating detectors, shown in tables 1 and 2 by comparison of analyzed samples with detector readings, and the fact that the indications are immediate and at the location of sampling are distinct advantages to mine officials and mine inspectors.

Every coal mine known to give off explosive gas should be provided with at least one of these detectors to aid the officials in planning for control of ventilation and checking firebosses' and mine-foremen's reports of gas, thus preventing hazardous gas conditions in the mine. Certainly every mine inspector should have one or both of these instruments and should use it enough to become familiar with it. These devices afford the mining man an opportunity to approximate closely the methane content of any part of the mine atmosphere and for practical purposes give data as to explosive gas approximating the value of the information obtained by chemical analysis. However neither of these devices gives information as to oxygen or carbon dioxide content and in this respect both are inferior to the flame safety lamp.

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